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NOTS TP 4050

COURSE OF THE REACTION IN A DETONATION WAVE OF A MIXED HIGH EXPLOSIVE

Translated by

Marvin E. Backman

Research Department

ABSTRACT. This report is a translation from the Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki on a subject that is of interest to warhead design and research. Some experimental data are presented on the velocity of detonation of different mixtures of high explosives of which there is evidence that the reaction occurs in phases.

U.S. NAVAL ORDNANCE TEST STATION
China Lake, California
March 1966

U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

J. I. HARDY, CAPT., USN
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Technical Director

FOREWORD

The text of this report was translated from a Russian journal at a time that no regularly scheduled translations were made. The article discusses results of Soviet research that have a direct bearing on the understanding of the principles of warhead operation and design. Four other translations of Russian articles were made to assist research and design workers in the warhead field: NAVWEPS Report 9042, NAVWEPS Report 9043, NAVWEPS Report 9044, and NAVWEPS Report 9046.

This article "Course of the Reaction in a Detonation Wave of a Mixed High Explosive," by A. Ya. Apin, I. M. Voskoboinikov, and G. S. Sosnova was published in Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, 1963, No. 5, pp. 115-7.

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COURSE OF THE REACTION IN A DETONATION WAVE OF A MIXED HIGH EXPLOSIVE

by

A. Ya. Apin, I. M. Voskoboinikov, and G. S. Sosnova

The development of a theory of high explosives requires a knowledge of the kinetics of the reaction at the front of the detonation wave. The complexity of the study of this question lies in the lack of direct methods of recording the conditions of the products of detonation in the wave and the impossibility of extrapolating data on the thermal decomposition of high explosives at lower T and p to a region of such high temperature T and pressure.

Some information or the progress of the reaction under the conditions of a detonation wave can be obtained by studying the dependence of the velocity of detonation D, m/sec, on the diameter of the charge d, mm, of mixed H.E. consisting of explosive components of different reaction properties. As a consequence of the different times of reaction of the decomposition of these components the growth of the velocity of detonation with increases of the diameter of the charge will not proceed continuously but by the attainment of a fixed value for some quantities corresponding to the completion of intermediate states of reaction. Analogous dependences D(d) may take place also for mixtures of the oxidizer-fuel type if the subreaction after the decomposition of the explosive components demands for its completion a significant interval of time because of the difficulty of diffusion under the pressure of the detonation of the condensed high explosive. Some experimental data are presented below on the velocity of detonation of different mixtures of high explosives at the front of which there is observed a course of reaction consisting of phases.

Mixtures were studied first consisting of explosive oxidizers and nonexplosive fuels; the degree of passage of the subreaction can be judged from the increase of the velocity of detonation. In Fig. 1 the relation D = D(d) is presented for a suspension of lampblack with sizes of the particles close to a micron in tetranitromethane 10/90 (curve 1); a mechanical mixture of ammonium perchlorate with paraffin 90/10 with grain dimensions 0.01 mm, ρ_o - 1.0 g/cm^3 (curve 2) and trotil (TNT) with colloidal boron 90/10, ρ_o = 0.65 g/cm^3 (curve 3). Common to the indicated mixtures is a constancy in some interval of charge diameters of an nonideal detonation velocity (pseudoideal velocity), the magnitude of which corresponds to the energy of decomposition of the oxidizer.

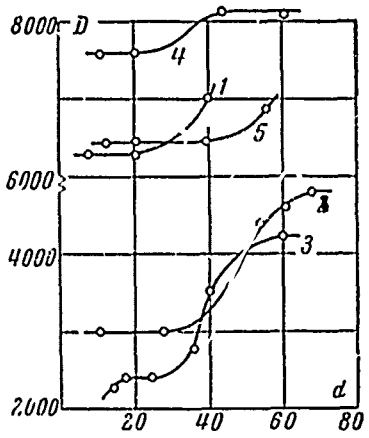

FIG. 1.

The increase in the velocity of detonation of the mixture of trotil and colloidal boron at charge diameters greater than 40 mm shows that metals (in particular boron) can burn up in the detonation wave of condensed explosives with the liberation of an additional amount of heat which leads to the growth of the detonation velocity, a fact that frequently comes in for doubt in the consideration of powerful metallized high explosives. The velocity of detonation was measured by ionization and optical methods, the error in both cases did not exceed 50 m/sec.

In Fig. 1, a curve D = D(d) is also placed for a mixture of hexogen and ammonium nitrate 58/42, grain sizes 0.1 mm (curve 4) and a suspension of coarse grained hexogen of particles 1.0 ÷ 1.6 mm in gelatinized 2% plexiglas tetranitromethane 30/70 (curve 5). The value of the pseudoideal velocity corresponds to an energy of decomposition of hexogen and tetranitromethane at the front of the wave. In the latter it is easy to verify, measuring the velocity of detonation in the mixture, where a component that replaces inert material (ammonium nitrate or coarse crystalled hexogen) is not progressing in decomposition in the wave. From the values that are presented in Table 1, it is seen that the velocity of detonation for mixtures of hexogen with sodium chloride and suspensions of hyposulphite in tetranitromethane differ little from the corresponding pseudoideal detonation velocities. In Table 1 are also given the values of the ideal detonation velocity D_i of the mixtures that were studied.

Pseudoideal detonation velocities are successfully observed also for mixtures whose explosive components decomposed in the wave at short times. In Fig. 2, as an example, a curve D(d) is presented for a suspension of hexogen of particle size 0.3 - 0.4 mm 30/70 and trotil 20/80 in tetranitromethane (curves 1 and 2), and also for a solution of dinitroethane in tetranitromethane 76/24 (curve 3). The analysis of the values of the

detonation velocities in this case may be carried out by means of the calculations of the parameters of the detonation wave.[1]

TABLE 1. The Pseudoideal Velocity of Detonation D_1 of H.E. Mixture Corresponding to Decomposition of Only One Component

Explosive Material	ρ_o	D_2	D_1
58% $(CH_2NNO_2)_3$ + 42% NH_4NO_3	1.73	7,600	8,100
58% $(CH_2NNO_2)_3$ + 42% NaCl	1.89	.....	7,500
70% $C(NO_2)_4$ + 30% $(CH_2NNO_2)_3$	....	6,400	7,500
70% $C(NO_2)_4$ + 30% $Na_2S_2O_3$	....	.....	6,200
90% NH_4ClO_4 + 10% Paraffin	1.00	3,000	4,800
NH_4ClO_4	1.00	.....	2,900
90% $CH_3C_6H_2(NO_2)_3$ + 10% B	0.65	2,400	4,200
$CH_3C_6H_2(NO_2)_3$	0.65	.....	3,800

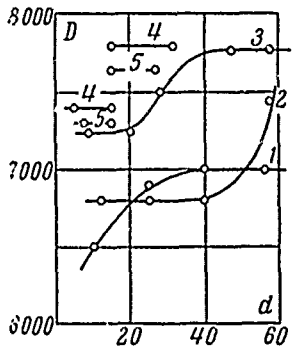

FIG. 2.

It is assumed that the reaction of the wave proceeds in the following way: at first the explosive components are completely decomposed in the characteristic volume, then after the elapse of some interval of time there begins an effective reaction of the subreaction between the products

[1] Apin, A. Ya., and I. M. Voskoboinikov. "A Calculation of the Parameters of the Detonation Wave of Condensed High Explosives," PMTF, 1960, No. 4.

of their decomposition. The agreement of the results of the calculation of the detonation velocity D_3, corresponding to the completion of the first stage of the reaction with the experimental values of pseudoideal detonation velocity D_2 for a series of explosive mixtures serves well to verify such a scheme of the course of the reaction.

In the investigation of liquid explosive solutions the authors observed a strong dependence of the velocity of detonation on the diameter of the charge, although it practically completely disappeared for individual liquid and monocrystalline high explosive. Sometimes this dependence has a very unique form: for example with solutions of tetranitromethane in nitrobenzol 76/24 and in kerosene 88/12 (curves 4 and 5, Fig. 2) there are at some diameters of the charge, depending on the thickness and the material of the liner, detonation velocities differing by 400 m/sec with equal probability of these values. At the same time the temperature of the detonation front, measured by electro-optical methods, are separated by 500°K.

The fundamental cause of the pseudoideal detonation velocities that are observed is the progress by stages of the reaction at the front of the detonation wave of mixed high explosives, due to the kinetics of the decomposition of the explosive components. A whole series of factors have an influence on the rate of liberation of energy in the wave (the reactive property of the components and the heat of their explosive reactions, the dispersion and the percent of the compounds of the mixture) the action of each of which for a specific explosive mixture is frequently difficult to recognize. However, decreasing the dispersion of a component in the mixture always increases the probability of observation of a pseudoideal velocity of detonation since it increases the time difference between the decomposition of a component and the following subreaction. Thus, if for a suspension of fine crystalline hexogen of particle size close to 0.1 mm in gelatinized tetranitromethane (curve 1, Fig. 3) the growth of detonation for increasing charge diameter occurs continuously, then for particle sizes 0.3-0.4 mm (curve 2) at charge diameters of 20-50 mm the fixation of retardation of the subreaction between the products of decomposition of tetranitromethane and hexogen works out well. Increases of particle sizes up to 1.0-1.6 mm and 3-4 mm leads to the failure of the coarse metallic hexogen to decompose in the wave at small charge diameters (curves 3 and 4).

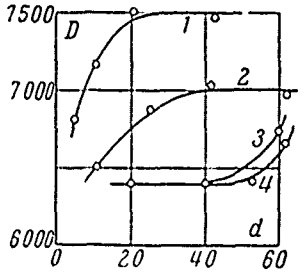

FIG. 3.

The consideration of the curves D(d) for the suspension of hexogen in tetranitromethane (Fig. 3) permits one to discover that for increases of particle size greater than some value (1.0-1.6) the diameter of the charge in which the hexogen decomposes ceases to depend on its dispersion. The quantity d_1 characterizes the delay time of the decomposition of hexogen in the volume (for the surface reaction it would be a function of particle size) and decreases for increases of pressure in the detonation wave.

Placing a grain of coarse crystalline hexogen of sizes 1.0 to 1.6 mm in liquid H.E., for which the pressure in the detonation wave varied from 180,000 to 220,000 atm, it was possible to trace the decrease of the diameter d_1 with the growth of pressure (Fig. 4). If it is considered that the reaction proceeds effectively to this time while the pressure is not decreased in fixed contribution, then the delay time of the reaction will be to a first approximation proportional to the diameter d_1 and for pressures of 180,000, 190,000, and 205,000 atm and proportional to the numbers 8:3:2.

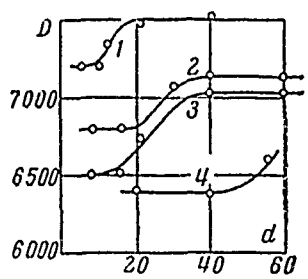

FIG. 4.

Curves 2 and 3 correspond to one and the same pressure p = 190,000 atm, but different temperatures of the explosive products of liquid high explosives: curve 2--T = 3200°K, curve 3--T = 4200°K, differing by 1000°K. The grain of hexogen was decomposed at the same charge diameters. Curve 1 corresponds to a pressure p = 205,000 atm, but curve 4--p = 180,000 atm. Liquid high explosives have a small critical diameter and for these there is proposed a comparatively small time of reaction of decomposition in the detonation wave.

The examination of the curves D(d) for suspensions of hexogen in liquid explosives that were carried out indicate the possibility of using the phenomena of pseudoideal detonation velocities for an estimate of the time of the reaction of decomposition of the explosive constituent in the wave.

Ideal detonation velocities corresponds to a compound of the products of detonation which depend only on the contents C — H — N — O and the temperature and pressure of the detonation; all the parameters of the ideal detonation wave of a mixed high explosive can be calculated in

exactly the same way as is done for the individual H.E.[1] It should only account for the peculiarity of the progress of the reaction in a detonation wave of mixed high explosive, associated with the fact that at the start the explosive components are decomposed in a characteristic volume and then a prereaction occurs in the detonation products. In the case when the composition of the detonation products in the first stage is energetically more favorable than after the subreaction, the first stage of the reaction is responsible for the ideal velocity of detonation (this applies to mixtures of the type of pentolite, Table 2).

TABLE 2. Pseudoideal Detonation Velocities of Mixtures of High Explosives, Corresponding to the Decomposition of Two Constituents

Explosive Material	ρ_o, g/cm^3	D_2, m/sec	D_3, m/sec	D_1, m/sec
80% $C(NO_2)_4$ + 20% $CH_3C_6H_2(NO_2)_3$	1.64	6,800	6,800	7,600
70% $C(NO_2)_4$ + 30% $(CH_2NNO_2)_3$	1.70	7,000	7,000	7,500
76% $CH_3CH(NO_2)_2$ + 24% $C(NO_2)_4$	1.42	7,250	7,000	7,800
50% $C(CH_2ONO_2)_4$ + 50% $CH_3C_6H_2(NO_2)_3$	1.65	7,450	7,550	7,450

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